WORK PRACTICES TO REDUCE HEAT STRAIN

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ABSTRACT

Body temperature must be maintained within narrow limits to prevent a deterioration in function. Health and even life can become jeopardized by a rise in core or deep body temperature. Maintenance of body temperature is dependent upon a balance where heat loss equals body heat production plus heat which is gained from the environment. The work practices described in this paper affect one or more of these variables in the heat balance relationship.

The benefits of individual characteristics such as physical fitness and acclimatization for heat stress are discussed. Factors that are important for the selection of work and rest scheduling are also outlined.

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INTRODUCTION

Regulation of deep body temperature is important to prevent impairment of optimal physical and mental work capacity. Core temperature is normally near 37° C and should not exceed 38° C to prevent any impairment in function from developing. An individual can only tolerate an internal temperature exceeding 41° C for a brief period of time. If the temperature of the body is to remain constant, heat loss must equal heat production and heat gain from the environment.

The human body continuously produces heat which helps maintain core temperature close to 37° C. When a person engages in physical work the muscular activity also produces heat since only a portion of the energy released in the metabolic breakdown of food stuffs is transferred into external work. The harder a person works the more heat they produce and must dissipate. This factor exerts a strong influence on the ability to perform work in a hot environment.

Characteristics of the environment influence how easily heat is transferred away from the body. If the skin is much warmer than the air, convective and radiative exchanges combine with evaporation to dissipate body heat. When environmental temperature approaches skin temperature then only evaporation can

reduce body heat. If environmental temperature exceeds skin temperature then the body gains heat and all the heat loss must be accomplished by evaporative mechanisms. Sources of radiant heat can increase the heat gain from the environment. High levels of humidity reduce the ability of the body to cool itself by evaporation.

The objective of this paper is to describe some work practice considerations that can reduce the physiologic strain on the worker. Awareness of such techniques by employers and health and safety committees can assist in improving work tasks performed in hot environments. Companies that have lengthy experience with heat stress will likely have evolved their production practices so that they incorporate some or all of these suggestions. For example, the need for acclimatization of workers to reduce heat strain has long been recognized by many of these employers. This will not likely be the case for new employers or those with infrequent heat stress periods. It is for these situations that the material in this paper may be of most value.

RESPONSE TO HEAT STRESS

Heat stress results in the occurrence of physiological changes within the body to prevent a rise in body core temperature. Heart rate increases and the small blood vessels in the skin dilate. Blood is directed away from the splanchnic and

renal regions as well as non-working muscles. If not enough heat can be released by this re-distribution of blood then heat sensors activate the sweat glands to release fluid. This sweating mechanism is only effective in increasing heat loss if the perspiration is removed from the skin by evaporation. In high humidity environments large quantities of body fluids can be lost with very little cooling of the body. Under these conditions the worker's ability to do the job is affected.

The degree to which a person responds to a specific heat stress situation is influenced by characteristics of that individual. Physical fitness, state of heat acclimatization (adaptation to heat) and body size are examples of factors that influence the physiologic strain that the person experiences. Excessive working exposure to a hot environment can bring on a variety of physical disorders ranging in severity from discomfort to death. A description of these disorders can be found in Appendix A.

APPROACHES TO REDUCE HEAT STRESS

There are essentially two approaches that can be used to reduce heat stress and thus decrease the extent of strain experienced by workers. An engineering approach usually attempts to modify the environmental factors that contribute to heat stress. This modification includes such things as the use of air cooling equipment, humidity reduction, increasing air movement

and shielding radiative heat sources. These techniques can be very effective in some work situations but are not practical or possible in others. An alternate approach is to use work practice techniques to reduce the strain. This approach considers how the work is done and thereby decreases the body heat generated from metabolism and/or reduces the buildup of body heat. These work practice techniques are practical and effective in reducing heat strain when working in elevated temperature environments.

WORK PRACTICE TECHNIQUES

Drinking Water

Sweating is the primary mechanism for releasing body heat under heat stress conditions and it is imperative that workers be able to replace the lost body fluids during the work period. Workers exposed to intense heat may lose as much as 6-7 litres of sweat in the course of the working day (Astrand, 1977). Drinking water must be located close to workers in all high heat situations. Workers should be encouraged to drink water because the sensation of thirst is an inadequate drive to stimulate a large intake of fluids in a short period of time (Leithead and Lind, 1964). The water should be cool (10-15^{o}C) and cups should be supplied since people tend to consume greater volumes when drinking from a cup than when drinking from a fountain. Workers with continuous exposure to high heat areas should make a habit

of drinking fluids every 15-20 minutes and more than necessary to satisfy thirst. The necessity of adding salt to the drinking water is controversial. There are some indications that the use of salt tablets or salted drinking fluids may interfere with the bodies natural adaptive response to reduce the amount of salt in sweat (Goldman, 1980). Since excessive salt intake can cause nausea, vomiting and diarrhea and the ocurrence of cramps is readily reversible with salt intake it is suggested that salted water not be used until an individual experiences symptoms of heat cramps. This is the same position that the military recommends (Goldman, 1980). One other potential problem with salted water is the consumption of it by individuals who are on a restricted salt diet for medical reasons (NIOSH, 1980).

Acclimatization

Acclimatization is the process of adapting to one's environment. In the case of heat stress if a person is regularly exposed to a hot environment their body will undergo adjustments so that the physiologic strain is reduced. The improvement in heat tolerance seen after a few days exposure is associated with increased sweat production and a lowered skin and body temperature. The onset of sweating occurs at lower skin and core temperatures resulting in less of an accumulated heat load. Sweat production can increase by as much as 100 per cent with acclimatization (Leithead and Lind, 1964). This increased sweat production provides the capability for a more effective cooling

of the skin through evaporative heat loss. The lowered skin temperature provides for a better cooling of the blood flowing through the skin. Thus, the amount of blood flow to the skin is reduced which in turn decreases the strain on the cardiovascular system. Heart rate for a given work load is reduced and central circulation is improved following acclimatization.

Large amounts of sweat loss can result in salt depletion since sweat contains varying concentrations of different salts. The process of acclimatization affects the salt concentration of sweat in that the amount of salt per volume of sweat decreases as acclimatization improves (Astrand, 1977). For this reason, and the fact that the average Canadian diet contains an excess of salt, supplementation of salt may only be necessary during the first few days of heat exposure.

Numerous acclimatization schedules exist either to reduce the time required for acclimatization or to ensure that full acclimatization has been attained. Most of the benefits occur in the first 3 or 4 days and almost complete adaptation develops in 7-11 days. If muscular work is involved in the exposure to heat, physical work should be included in the acclimatization period. One schedule of acclimatization calls for the person to work at a 50% anticipated total work load/time exposure on the first day, followed by 10% daily increments to reach 100% exposure on the sixth day (NIOSH, 1972). Simultaneous exposure to both heat and exercise is recommended for optimal heat acclimatization (Astrand, 1977).

The loss of acclimatization is often a concern when individuals are absent from heat exposures because of holidays or sickness. Although effects of heat acclimatization persist for several weeks, some impairment in heat tolerance may be detected for a few days following return to work (Astrand, 1977). Since the adaptive response is not lost quickly, Goldman (1980) suggests that a formal schedule for reacclimatization is not as important as for initial acclimatization. The situation where workers are returning after an illness presents additional complications. In this circumstance it is important that the plant or personal physician is aware of how the return to work in the heat interacts with the specific illness.

Training and Education

It is very important that both employees and their supervisors are able to recognize the initial signs of heat strain in order to prevent the deterioration of health (see Appendix A for symptoms of heat stress disorders). The workers should be made aware of the need for fluid consumption and attempt to monitor their fluid balance by weighing themselves before and after a work shift. It is also very important that supervisors be aware of both the environmental factors and the characteristics of individuals that contribute to heat strain. This information will allow them to anticipate circumstances which may make workers more vulnerable. This information should also be incorporated into decisions of worker assignment to

specific work tasks. New employees, people returning to work following sickness or holidays, and repairmen who do not normally work in hot areas are more vulnerable than regularly exposed individuals. The first hot spell is often more stressful, as are periods of high humidity. When ambient temperatures are greater than skin temperatures a small individual is at a disadvantage because of their high surface area to body mass ratio (Strydon et al., 1971). The importance of how strenuous the task is as a contributor to heat balance should be outlined. The need for rest pauses and the importance of taking them in a cool location are vital information for workers and supervisors to be aware of.

Fitness

Physical fitness also affects how well an individual can tolerate heat stress. Physical training appears to increase sweat gland secretion. The increased metabolic rate during training requires a high degree of thermoregulation and apparently this demand induces an increased sensitivity of the sweat glands to the central sweating drive (Astrand, 1977). Physical training also improves the circulatory capability to supply blood to the peripheral circulation while still meeting the blood flow requirements of the working muscles (Drinkwater, 1976). The maximum amount of blood that the heart can pump per minute increases with physical training and thus there is a greater reserve capacity to cope with the changes induced by exposure to heat.

Clothing

The amount and type of clothing can dramatically affect the heat strain experienced by a worker. In a moist hot climate where environmental temperature is less than skin temperature it is beneficial to wear as little clothing as possible provided that sources of radiant heat are not present. When sources of radiant heat are present or environmental temperature is high then clothing may provide protection for the worker. Ideally the clothing should permit free circulation of air. Cotton fabrics, which have a high vapour permeability and high thermal conductivity are beneficial in hot/wet environ-ments. They absorb sweat very efficiently and permit the rapid flow of heat from the body. Woolen fabrics have a low thermal conductivity but a high vapour permeability and would provide protection from radiant heat while still allowing perspiration to evaporate.

Scheduling

Though acclimatization and fitness improvement are very useful ways to reduce heat strain there is a limit to the role that they can play in a total program to manage heat stress. Work scheduling provides powerful complimentary assistance for heat strain reduction.

One of the most effective uses of scheduling to reduce heat

stress is to perform strenuous tasks during the coolest times of the day. This likely will not be possible for all tasks but things such as repair of machines or heavy clean-up may be done during cooler periods. In some cases work environments are just too hot to allow continuous exposure of the worker. When this is the case a schedule of intermittent work with sufficient rest periods is necessary. This can prevent the accumulation of heat to dangerous levels and also allows the release of heat before the person returns to the task. While the person is resting there is little metabolic heat generated and this allows the amount of heat released to exceed heat produced.

The American Conference of Governmental Industrial Hygienists has published threshold limit values for intermittent heat exposures for different metabolic loads (ACGIH, 1981). Time weighted exposure limits have also been calculated. In general, the greater the heat stress the longer are the rest periods that are required. However, the timing of the breaks is important as is the total length of rest periods during the day. Brouha (1967) describes a situation where one hour work, one hour rest intervals presented more of a physiologic strain than did half hour work-rest periods. With the one hour changes, workers were experiencing higher heart rates in the afternoon. When the half hour rotations were used the cardiovascular reaction to the work task in the afternoon was the same as in the morning. Brouha (1967) explains that the one hour work periods produced too great a heat load to allow recovery in one hour while the heat load of

a half hour work period could be relieved with a half hour rest. This schedule prevented the accumulation of body heat later into the work shift. Brouha concludes that in a warm environment the principle of alternating short periods of work and rest should be applied whenever possible.

The rest place environment is very important in determining how effective the rest pause is in reducing the physiologic heat load. Air conditioned rest areas influence whether a rest pause is sufficient for all physiologic parameters to return to equilibrium before returning to the task. Maintaining a low humidity within the rest environment assists in recovery since sweat evaporation is enhanced and also the clothing will dry. It is important that rest breaks be long enough to allow full recovery; if restoration is not complete the deficit will accumulate and performance later on in the shift will be affected. Laboratory experiments have demonstrated the favorable effect of resting in a cool environment (Brouha 1967, Kamon 1979). When rest periods were taken in a cool environment, the heart rate remained at a lower level during the whole experiment and barely increased as more work cycles were performed. On the contrary, when the heat exposure was continuous, the cardiac stress increased progressively and the heart rate rose as the work task was continued.

Establishing adequate rest periods is not an easy task since so many factors affect their recuperative value. Close

collaboration of a physiologist and an industrial engineer is required so that changes in rate of work and production can be evaluated together with changes in physiological reactions.

Another aspect of scheduling which will influence heat strain under certain conditions is work in different temperature environments. In this circumstance there are no clear divisions between work and rest but rather the job involves rotation between different environments. How the rotation is arranged can affect resistance to heat strain. There appears to be an advantage in performing the greater strain tasks first and then proceeding to the less stressful task rather than vice versa (Brouha, 1967). For example, equal work loads in different environments resulted in a body temperature increase of $0.6^{o}F$ ($0.3^{o}C$) when rotation was from cool to warm but an increase of only $0.2^{o}F$ ($0.1^{o}C$) when rotation was from warm to cool. Maximum heart rates were the same for both rotations but cardiac debt was greatest in the cool to warm sequencing. One, two and three minute recovery heart rates were higher for the cool to warm sequencing. When the work load in the two environments was increased the rotation effects became more pronounced.

Brouha feels that the difference between these reactions can be explained on the basis of heat dissipation. When the person works first in the heat, he is able to "pay back" part of the heat debt while he continues working in a cooler environment. This is not possible when the sequence is reversed. Since there

is a greater accumulated heat debt, the recovery processes (thermal and cardiovascular) take place more slowly.

These findings suggest that in industrial operations work cycles should be organized, if possible, according to the schedule: warm work-cooler work-rest period. Under these conditions and for the same amount of work, the duration of the rest periods could be reduced without increasing the physiological cost of the cycle.

The same principle would be of benefit when tasks of different work intensity must be done in the same environment. In this case if the higher intensity task is done first then some recovery can occur during the time spent on the less strenuous task.

Work Process Modification

Since heat stress results from a combination of environmental factors and metabolic heat production, reducing the metabolic generation of heat will reduce the heat strain that is experienced. Reducing work pace, increasing the number of workers to do a task or changing the mode of work can all reduce the metabolic heat production and/or cardiovascular strain.

The reduction of work pace when conditions are hot will likely occur naturally in most situations. Supervisors should be sensitive to the need to slow down under hot conditions. Problem

situations can develop when motivation is high (eg. piece work) or if the work is not self-paced (assembly line production). When these situations exist it should be the supervisor's responsiblity to modify the work pace to within safe levels.

Adding more people to a work crew can be effective in reducing the demand on any one individual by either increasing the length of rest periods or decreasing the work intensity required of each individual. In studying 3 and 4 man crews, Brouha (1967) found that physiological strain was lower with the 4-man crews but also found that productivity per worker was higher in this group. This was attributed to the fact that less time for rest was needed per man. The final result of using the 4-man crew versus 3-man crew was that the increased output was sufficient to cover more than the cost of the additional worker. The greater the physiological stress is, the greater is the improvement achieved by adding an extra worker (Brouha, 1967).

Many industrial operations can be made easier if the position of the body (static contraction), the nature of the motion (dynamic contraction) and the speed of motion (rate of contraction) are so arranged that the physiological cost of the job is reduced to a minimum (Brouha, 1967). This essentially involves changing how the work is done. One way to accomplish this is to introduce mechanical aids into jobs that involve hard manual labour. An example of such a mechanical aid in material

handling would be the two wheeled hand cart. Rather than having to bend over, pick something up and carry it, the worker now essentially only has to push or pull the loaded hand cart. Mechanical aids such as these are either presently available or need to be designed for the specific work task. Work which involves prolonged standing can be additionally stressful in the heat because of the hydrostatic pooling of blood in the legs. Postural changes can also be effective in reducing worker strain. Workers performing a skimming operation to remove impurities from molten metal attained heart rates of 160 beats/min when the tank was at shoulder height but only had heart rates of 112 beats/min after a platform was built to lower work height. A final example of a simple work change to reduce strain is an example of a worker loading 22 kg bags on a platform. The usual process was to stack the bags seven high to a height of approximately 1.8 metres (6 ft.) but it was found that the energy spent by the worker in loading the upper two courses was too great in relation to loading all five others. The time taken for that part of the operation was also greater so a double economy of time and physiological cost was achieved when the load was limited to five courses of bags.

Work process modification can be very effective in reducing physiologic strain but unfortunately there are few universal solutions and thus very often each work task has to be evaluated on its own requirements. When making work process changes to reduce strain it is important to determine the effects on the workers as well as on such things as output and cost.

CONCLUSION

Workers must be protected from too great a rise in core temperature when working in a hot environment. The heat stress that the person is exposed to is affected by the work environment and characteristics of the work task. Modification of either of these two factors can reduce heat strain. Work practices can substantially reduce heat strain within a hot environment. To optimize this reduction the principles for reducing heat strain need to be incorporated into the specific circumstances of each work place.

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APPENDIX A

Excessive working exposure to a hot environment can bring about a variety of health disorders among workers. These disorders and their associated symptoms are outlined below:*

Transient Heat Fatigue

Transient heat fatigue refers to the state of discomfort and psychological strain arising from prolonged heat exposure. Workers uncclimatized to the heat are particularly susceptible, and can suffer, to varying degrees, a decline in task performance, coordination, alertness, vigilance, and become irritable and depressed. The severity of transient heat fatigue can be lessened by a period of gradual adjustment to the hot environment.

Heat Rash

Heat rash, also known as prickly heat, is likely to occur in hot and humid environments where sweat is not easily removed from the surface of the skin by evaporation. The sweat ducts are plugged, the sweat glands inflamed, and a rash soon appears. When extensive, or when complicated by infection, prickly heat can be so uncomfortable as to reduce a worker's performance. This condition can be prevented by resting in a cool place at regular intervals and by taking a shower after each workshift.

Fainting

A worker who is not used to hot environments and who stands erect and immobile in the heat may simply black out. With enlarged blood vessels in the skin and in the lower part of the body, blood may pool there rather than return to the heart to be pumped to the brain. Once lying down, the worker should soon recover. By moving around, and thereby preventing blood from pooling, further fainting while standing can be prevented.

Heat Cramps

Heat cramps are painful spasms of the working muscles of those who sweat profusely in heat, who drink large quantities of water, but fail to replace their bodies' salt

* from Hot Environments U.S. Dept. of Health and Human Services, Public Health Service. U.S. Government Printing Office, Publication No. 80-132. Washington, D.C. 10402, 1980.

loss. The drinking of water tends to dilute the body's extracellular fluids, while it continues to lose salt. Soon, the low salt in the muscles causes painful cramps. The affected muscles may be part of the arms, legs, or abdomen, but tired muscles (those used in performing the work) are usually the ones most susceptible to cramps. Cramps may occur during or after work hours, and may be relieved by drinking 1 glass of water containing 1/2 teaspoon of salt.

Heat Exhaustion

Heat exhaustion includes several clinical disorders, all of which reveal similar symptoms. The condition is caused by the loss of fluid in sweating, sometimes by the loss of salt and often by both. The worker with heat exhaustion still sweats, but experiences extreme weakness or fatigue, giddiness, nausea, or headache. In more serious cases, the victim may vomit and/or lose consciousness. The skin is clammy and moist, and complexion is pale or flushed, and the body temperature is normal or slightly higher. The unacclimatized, the physically unfit, and the obese are more prone to develop heat exhaustion.

In most cases, treatment is simple: have the victim rest in a cool place and give him or her plenty of lightly salted liquids. Mild cases may result in spontaneous recovery with this treatment. Severe cases may require care for several days. There are no known permanent effects. CAUTION - PERSONS WITH HEART PROBLEMS OR THOSE ON A "LOW SODIUM" DIET OR INTAKE MUST CONSULT A PHYSICIAN ON WHAT TO DO UNDER THESE CONDITIONS.

Heat Stroke

Heat stroke is the most serious of the health problems which can arise while working in hot environments. It occurs when the human thermo-regulatory system simply breaks down under stress, and sweating stops. There may be little warning to the victim that a crisis stage has been reached. Just why this happens is not known, but when it does, the body's only effective means of getting rid of excess heat is gone.

A heat stroke victim's skin is hot, dry, and usually red or spotted. Body temperature is 40.5^{o} C or higher and rising. He or she is mentally confused, irritable and may complain of feeling chills. If the worker is not taken out of the hot environment at this early stage of heat stroke and cooled off rapidly, then more severe symptoms will occur, such as unconsciousness, delirium, and convulsions, leading to death.

An ambulance should be summoned immediately, but first aid is also vital. The worker should be taken to a cool area, his or her clothes thoroughly soaked with water, and the body vigorously fanned to increase cooling. Further treatment at a medical facility will continue the cooling process and monitor for a variety of complications which may accompany the disorder. Early recognition and treatment of heat stroke after it occurs are the only means of preventing permanent brain damage or death. Good physical fitness and heat acclimatization will increase a person's heat tolerance but they will not give immunity against heat stroke. Those suffering from chronic disease, the obese, and the alcoholic are more susceptible. The person who has prior history of heat illness is also more prone to get this heat illness again.